Group photo of the GTS team.

SIGNAL PROCESSING GROUP (GTS)

HEAD OF THE GROUP RESEARCH REPORT

The Signal Processing Group (GTS) is devoted to produce quality research to advance in both the theoretical aspects of signal processing and its applications. The areas of application include industry, underwater acoustics, medicine and fine arts.

Within these areas the GTS mainly focuses in some research lines in which the group has proven professional experience. Some of them are: signal processing applied to ultrasonic and impact-echo methods, signal processing techniques applied to bioacoustics and passive acoustics monitoring, signal processing algorithms for surrogate data generation and signal modality, image and video processing for biomedical applications, and technology for the arts. A complete list of research activities can be found at http://www.iteam.upv.es/group/gts/.

Among others, the GTS has been granted this year with a DG Environment European Research Project.

1.- PROJECT ACTIVITIES

The GTS has continued researching in the already stablished research lines as well as in some other emerging activities. A short summary of the main activities being accomplished in the group is given below:

Signal processing techniques applied to ultrasonic and impact-echo methods for the characterization of cementitious materials in the construction industry

Among the most consolidated research lines, the GTS advances in the use of signal processing for non-destructive testing, both for the detection and for the characterization of damage in construction materials. The research has produced innovative techniques for material characterization, damage location and tomography reconstruction (FANSIRAS and non-contact airborne ultrasound techniques are clear examples). These techniques have proven to be useful in the characterization of both natural and artificial stones.

The GTS collaborates, among some others, with the ICITECH (Institute of Science and Technology of the Concrete) and the Department of Civil & Environmental Engineering (University of Illinois) for the characterization of different types of global damage in cementitious materials using sonic and ultrasonic signals, and with the University College Cork and the Centro Superior de Investigaciones Científicas (CSIC) for the development of non-contact airborne ultrasounds.

Passive acoustics monitoring

The research line is focused on the use of Passive Acoustic Monitoring (PAM) to study marine mammals and anthropogenic noise. This is achieved by developing new acoustic instrumentation, such as the new SAMARUC acoustic recorder, as well as by sophisticated signal processing algorithms to detect and classify underwater acoustic events. Our goal is to improve the understanding of how

anthropogenic sounds impacts on the marine biodiversity, learn about animal bioacoustics and study the population abundance, seasonality and behavior of marine mammals in our seas and oceans. We combine traditional PAM techniques with recent advances in signal processing algorithms and representation techniques such as Big Data representations and deep learning. The group collaborates with the Instituto Español de Oceanografia (IEO) for the Spanish approach to the Marine Strategy Framework Directive (D11).

New version of the SAMARUC acoustic recorder with 2 TB of memory and enhanced bandwidth of 96 kHz.

Applications of biomedicine

We collaborate with the Clinical Area of Medical Image of the Hospital Universitario and Politécnico La Fe (GIBI230) in the processing and analysis of medical images. We provide a long experience in many fields of signal processing for the extraction of relevant information, detection of novelty, fusion of decisions when applied to image processing. During the last year, we have focused in extracting image biomarkers for the quantification of changes associated with the disease. We have also excelled in using the available tools to adapt the huge amount of information available in the image environment (DICOM, PACS, RIS) to the effective and real-time control of all quality aspects relevant to service excellence such as: radiation dose, number of procedures per process, temporary adjustment of demand, analysis of large consumers, costs, technological evaluation, etc. Finally, a recent research line consists in the use of automatic segmentation methodologies applied to Magnetic Resonance Images based on artificial intelligence and deep learning.

Graph Signal Processing

Graph Signal Processing (GSP) combines concepts emanating from two largely consolidated areas: signal processing and graph theory. From the perspective of signal processing it leads to a more general definition of a signal by assigning every sample value to the vertex of a graph. From the graph theory perspective, new graph transformations can be defined that extend classical signal processing concepts like filtering, prediction and spectral analysis. Signal processing on graphs is finding progressively new application in the areas of detection and classification due to its flexibility to model general dependencies between variables. Thus, GTS is currently developing new methods of classification, fusion of classifiers and signal surrogates based on GSP, which are applied to a variety of practical problems.

Emerging Signal Processing Techniques for Big Data Health Applications

GTS is currently working in the context of Big Data Health Applications. The proposed approach consists of multimodal fusion for biosignal analysis methods that include monitoring of the very variant dynamics of physiological phenomena sensed at high velocity on real time from several sources. We apply those methods in neurology and neurophysiology areas for the study and diagnosis of epilepsy, Alzheimer, and sleep disorders, collaborating in an interdisciplinary framework with physicians of the Hospital La Fe of Valencia. A multimodal analysis approach is considered in three specific scenarios: bimodal analysis of simultaneous recordings of fMRI (functional Magnetic Resonance Imaging) and EEG (electroencephalographic) recordings, analysis of EEG in combination with DTI (Diffusion Tensor Imaging) and ECoG (electrocorticographic) recordings for the case of epilepsy patients.

Technologies for the Arts (Soundcool)

Soundcool is an innovative system for collaborative Audiovisual creation using smartphones, tablets, Augmented Reality, computers, Open Sound Control (OSC), see Soundcool Introduction at https://youtu.be/zoZaVK7ysRM. The system started in 2013 being applied in education applications for primary, secondary and music schools, and in functional diversity. With the introduction of Soundcool control with Augmented reality in 2018 it was also proposed for professional applications, and we signed an agreement with Musikene Higher Center for Music Studies of the Basque Country for professional testing purposes. Soundcool is also being introduced at the New York University, and the collaboration with the Valencian Community Education Council continues with Soundcool courses at https://courses.edx.org and several Soundcool education proposals at http://soundcool.org/en/funding-soundcool/

1.1.- ONGOING PROJECTS

Name of the project: *Risk-based Approaches to Good Environmental Status (RAGES)*

Webpage of the project: *https://www.msfd.eu/rages/*

Summary of the project: *The RAGES project follows with the study of how human activities that take place at sea have an impact to the marine environment. However, in this new project a Risk-based approach is employed. The RAGES project is comprised of a consortium made up of competent authorities from Ireland, France, Spain and Portugal responsible for the implementation of the Marine Strategy*

Framework Directive in the North East Atlantic region (Celtic Seas, Bay of Biscay and Iberian) as well as Macronesian sub-regions. Our researchers study and propose methods to integrate the Risk-based approach in the acoustic modelling of the noise as well as in the Passive Acoustic monitoring of the different cetacean species. This innovative approach will help to establish anthropogenic noise levels that do not affect marine biota.

Funding entity: *DG for Environment (ENV), European Commission.*

Name of the project: *Spanish implementation of the Marine Strategy Framework Directive.*

Lisbon coordination meeting of the EU- RAGES project.

Summary of the project: *The IEO-UPV has been commissioned by the Ministry of Ecological Transition for the Spanish implementation of European Directive 11 (D11), within the Marine Strategy Framework Directive (MSFD). This new project has just started and all the new technological developments the group has made in passive acoustic monitoring will be employed. Particularly, our SAMARUC devices as well as our software will be employed to obtain ambient noise levels indicators used for validation of the acoustic models (according to D11.2).*

Funding entity: *Ministry of Ecological Transition.*

Name of the project: *BreakingBad: Predictive maintenance of tunneling machines*

SAMARUC retrieved from its mooring in the Bay of Biscay.

Summary of the project: *The goal of this project was to perform a prospective analysis of sensor data from tunneling machines to predict critical situations. As a result of this project, it was found how to detect temperature offsets in the motors from their current variables. This finding could prevent production breaks with high associated costs.*

Name of the project: *Study of possible improvements for the CAV assessment system.*

Summary of the project: *In the context of car damage repair by insurance companies there is a negotiation phase in which the car repair shops propose a budget and a human expert accepts or rejects the proposal. The goal of this project was to provide an automatic tool that could analyse the budget proposal and make a decision based on data from many previous cases. The developed system has proven to be very valuable and helpful since it can now recommend aspects to the car repair shops to adapt their initial budget proposals with objective arguments.*

Name of the project: *Advanced Fruit Inspection using multi-view techniques*

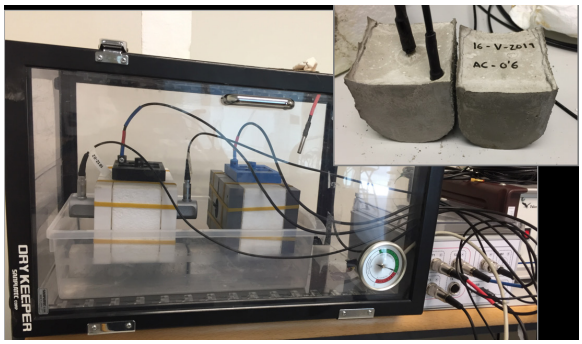
Summary of the project: *Sorting fruits is an application of computer vision. In order to be able to explore the whole surface of a fruit, several views are captured while the fruit is rotated. Analysing the different views independently is not optimum, since the degree of overlap between views is unknown. So in order to determine the degree of maturity or the number of defects, methods that consider all the views as a whole are needed. In this activity an ellipsoidal 3D model of the fruit is constructed from the collection of views. The different views are mapped onto the 3D model. Apart from the accuracy of the model, speed is a major concern in order to be able to translate the method into industrial inspection machines. Currently mode than 50 fruits per second (with about 10 views per fruit) can be analysed. The method has been successfully tested on tomatoes and oranges.*

Name of the project: *Development and application of non-destructive testing based on mechanical waves for the assessment and monitoring of rheology and self-healing in cementing materials (WAVECON)*

Summary of the project: *The project aims to develop new methods for non-destructive evaluation of fresh pastes, mortars and concrete (rheological characterization), and damaged systems (cracking) in which a regeneration or self-healing process takes place. During this year, we have established ultrasonic based methods to evaluate the basic rheological properties, such as viscosity and yield stress. We also have*

evaluated the self-healing due to autogenous healing properties (by the own nature of hydrated cement). For this last case, monitoring is done using ultrasonic techniques and non-linear acoustic resonance impact spectroscopy. Additionally, non-contact techniques have been also applied and avoid any touching with the specimens.

Funding entity: *Spanish Government. BIA2017-87573-C2-2-P.*



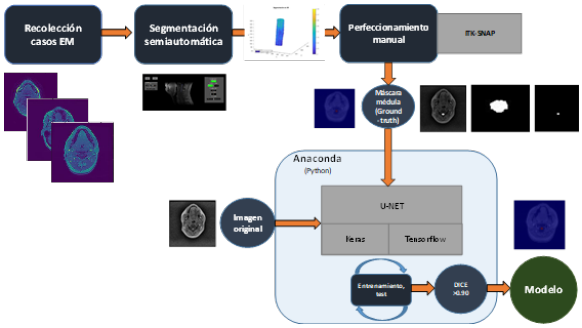
Ultrasonic monitoring of rheological properties

Name of the project: *Deep Learning for cervical cord segmentation in Multiple Sclerosis (DeepMedul)*

Summary of the project: The project aims to develop a new methodology of automated segmentation of the cervical spinal cord from MRI images. Using deep learning artificial intelligence techniques, it allows generating and storing massive data in Multiple Sclerosis patients, to increase knowledge about focal and diffuse alterations of demyelinating character in the cervical spinal cord, which currently leads to a high degree of disability and dependence in patients.

It aims to create a final product very close to the market, once its usability has been validated in a real environment such as the Clinical Area of Medical Imaging of the Hospital Universitario y Politécnico La Fe. With the design of a new type of structured report (implemented by the spin-off of the IIS La Fe, QUIBIM SL) that will integrate the most relevant information for the clinician, since the company has previous experience in the analysis service of LCR and will also contribute its know-how to the project.

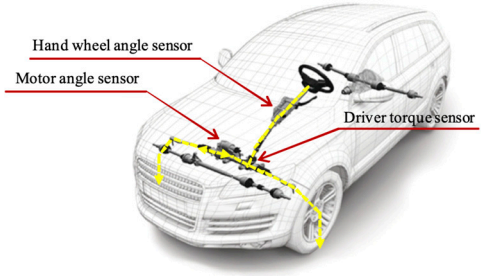
Funding entity: *Instituto de Investigación Sanitaria La Fé.*



Name of the project: *Informed Methods for Signal Synthesis (MISS)*

Automatic signal classification systems require a large enough training base to achieve a proper performance. In many applications there is no possibility of a sufficient number of labelled signals due to several reasons: a shortage of real signals in one or more of the classes, complexity, slowness and cost of measurement recording, complexity of manual labelling. This project addresses the synthesis of signals to increase the training base through advanced methods that enable to directly incorporate information from experts in the application domain or from some colateral sources. In this way, the synthetic signals could adequately reproduce the characteristics and properties of the actual signals that are essential in the training and validation of automatic classifiers. The proposed methodology is based on three advanced concepts. The first concept is a Generative Adversarial Networks type structure, in which two blocks compete with each other. The first block, based on the concept of Conditional Random Field, is discriminatory and must decide whether the signal at its input is valid or not. The second block, based on the concept of Surrogate Signal, is generative and supplies synthetic signals to the first one for its validation. In the first block as well as in the second, it is possible to define (inform) on the part of an expert or from other sources about the relevant properties of the involved signals. Thus, in the discriminative block design, it can be defined signal segments and interdependences between them. These later must be translated to sample interdependences in the generative block. The project considers two applications, one industrial and another of the medical field, for experimentation with the new methodology and its comparison with other reference methods of signal synthesis. The industrial application is relative to the design of Advanced Driver Assistance Systems that are progressively incorporated into the automotive industry. The medical application is devoted to the diagnosis support from functional magnetic resonance imaging synchronized with electroencephalography. The project also contemplates a more theoretical study on the influence of the training base size on the quality of the classifier design.

Funding entity: *Spanish Government, TEC-2017-84743-P.*



Location of some of the EPS sensors (figure from NEXTEER AUTOMOTIVE).

Name of the project: Soundcool: *Collaborative Music and Video Creation*

Webpage of the project: *http://soundcool.org.*

Summary of the project: *Soundcool is active this year with the grant to improve the training and employability of technical and management personnel of R&D&I through their employment by public research entities, within the framework of the National System of "Youth Guarantee" (Garantía Juvenil) and co-financed by the European Social Fund, Generalitat Valenciana and the Youth Employment Initiative (Iniciativa de Empleo Juvenil). An extension of the project Soundcool: Mobile and Digital Tools for Musical and Audiovisual Art Education 16-AC-2016 from Daniel and Nina Carasso Foundation has been also granted.*

Soundcool performance with a new Augmented Reality visualization app.

2.- RESEARCH RESULTS

2.1.- FEATURED PUBLICATIONS

· ***Multi-class Alpha Integration of Scores from Multiple Classifiers.*** *G. Safont, A. Salazar, L. Vergara. Neural Computation, 31, 806-825, 2019.*

Alpha integration methods have been previously used for integrating stochastic models and fusion in the context of detection (binary classification). This work proposes two new methods based on alpha integration to perform soft fusion of scores in multi class classification problems, one of the most common problems in automatic classification: separated score integration (SSI) and vector score integration (VSI). Equations are presented to optimize the parameters of these methods to achieve the least mean squared error (LMSE) or the minimum probability of error (MPE). The proposed alpha integration methods were tested on several sets of simulated and real data. The simulated experiments replicated a case of automatic detection and classification of three types of ultrasonic pulses buried in noise (4-class classification). For the experiments on real data, we performed automatic staging of two sets polysomnographic data from subjects with sleep disorders in three classes: wake, rapid eye movement (REM) sleep, and non-REM sleep. In all cases, the proposed methods performed better than the considered single classifiers and classical fusion techniques.

DOI: *10.1162/neco_a_01169*

· ***Multichannel Dynamic Modeling of Non-Gaussian Mixtures.*** *G. Safont, A. Salazar, L. Vergara, E. Gómez, V. Villanueva. Pattern Recognition, 93, 312-323, 2019.*

This paper presents a novel method that combines coupled hidden Markov models (HMM) and non-Gaussian mixture models based on independent component analyzer mixture models (ICAMM). The proposed method models the joint behavior of a number of synchronized sequential independent component analyzer mixture models (SICAMM), thus we have named it generalized SICAMM (G-SICAMM). The generalization allows for flexible estimation of complex data densities, subspace classification, blind source separation, and accurate modeling of both local and global dynamic interactions. In this work, the structured result obtained by G-SICAMM was used in two ways: classification and interpretation. Classification performance was tested on an extensive number of simulations and a set of real electroencephalograms (EEG) from epileptic patients performing neuropsychological tests. G-SICAMM outperformed the following competitive methods: Gaussian mixture models, HMM, Coupled HMM, ICAMM, SICAMM, and a long short-term memory (LSTM) recurrent neural network. As for interpretation, the structured result returned by G-SICAMM on EEGs was mapped back onto the scalp, providing a set of brain activations. These activations were consistent with the physiological areas activated during the tests, thus proving the ability of the method to deal with different kind of data densities and changing non-stationary and non-linear brain dynamics.

DOI:*10.1016/j.patcog.2019.04.022*

· ***A new surrogating method by the Complex Graph Fourier Transform.*** *J. Belda, L. Vergara, G. Safont, A. Salazar, Z. Parcheta. Entropy, 21-759, 1-18, 2019.*

The essential step of surrogating algorithms is phase randomizing the Fourier transform while preserving the original spectrum amplitude before computing the inverse Fourier transform. In this paper, we propose a new method which considers the Graph Fourier transform. In this manner, much more flexibility is gained to define properties of the original graph signal which are to be preserved in the surrogates. The complex case is considered to allow unconstrained phase randomization in the transformed domain, hence we define a Hermitian Laplacian matrix that models the graph topology, whose eigenvectors form the basis of a Complex Graph Fourier Transform. We have shown that the Hermitian Laplacian matrix may have negative eigenvalues. We also show in the paper that preserving the Graph Spectrum Amplitude implies several invariances that can be controlled by the selected Hermitian Laplacian matrix. The interest of surrogating graph signals

has been illustrated in the context of scarcity of instances in classifier training.

DOI: *10.3390/e21080759*

· ***Nonlinear Acoustic Spectroscopy and Frequency Sweep Ultrasonics: Case on Thermal Damage Assessment in Mortar****, V. Genovés, A. Carrión, D. Escobar, J. Gosálbez, J. Monzó, M.V. Borrachero, J. Payá, Journal of Nondestructive Evaluation, 38-61, 2019.*

An exhaustive study on thermal damage of Portland cement-based materials is addressed. Damage carried out at different temperatures on concrete between 40 and 525 C were assessed by means of microstructural, physical and nondestructive tests. Microstructural analysis (thermogravimetry and scanning electron microscopy) showed the principal changes of the Portland cement hydrated products for the different analysed temperatures. Compressive and flexural strengths remained constant or even increased at a low heating temperature range, while the mass loss increases. Dilatometry analysis revealed important information about deformation incompatibilities between the paste and the aggregate. These results have been correlated with nondestructive tests: nonlinear impact resonance acoustic spectroscopy (NIRAS) and ultrasonic measures. The dynamic modulus and ultrasonic pulse velocity have closely predicted the linear stiffness decay of the specimens. However, hysteretic parameter from NIRAS analysis exhibited a different trend from stiffness-related parameters, keeping constant until 250 C and suffering a huge increasing for 400 and 525□C. Ultrasonic attenuation computed with a broadband ultrasonic signal (chirp) revealed interesting information about scattering components inside the material, and is sensitive to interfacial transition zone between aggregate and paste in a large range of frequencies. The correlation between microstructural, mechanical and nondestructive techniques were carried out successfully. Nonlinear vibration and ultrasonic attenuation are non-conventional parameters that gave specific information about a complex damage process, such as a thermal attack in highly heterogeneous materials (e.g. Portland cement composites).

DOI: *10.1007/s10921-019-0599-0*

· ***Flipped Accumulative Non-Linear Single Impact Resonance Acoustic Spectroscopy (FANSIRAS): A novel feature extraction algorithm for global damage assessment.*** *A. Carrión, V. Genovés, G. Pérez, J. Payá, J. Gosálbez, Journal of Sound and Vibration, 432, 454-469, 2018.*

High amplitude non-linear acoustic methods have shown great potential for the identification of micro-damage in inhomogeneous materials such as concrete. Usually, these methods evaluate non-linearity parameters related to the hysteretic behaviour from the dependence of the shifts in both frequency and damping on the amplitude of the strain. A deep understanding of the reverberation phenomena has been obtained in order to introduce a novel signal processing approach called FANSIRAS (Flipped Accumulative Non-linear Single Impact Resonance Acoustic Spectroscopy). Traditional acoustic spectroscopy techniques, NIRAS (Non-linear Impact Resonance Acoustic Spectroscopy) and NSIRAS (Non-linear Single Impact Acoustic Spectroscopy), have been analyzed and compared with the brand new approach when providing quantitative information related to the degree of micro-cracking in thermal damaged concrete based materials. The new resonance-based algorithm demonstrates that the non-linear non-classical parameters can be determined through a single resonance frequency measurement, obtaining the expected sensitivity to internal damage. Its simplicity and robustness may be important in industrial applications.

DOI: *10.1016/j.jsv.2018.06.031*

· ***Improved visualization of large temporal series for the evaluation of good environmental status****, R. Miralles, G. Lara, J. Gosálbez, I. Bosch, A. León, Applied Acoustics, 148, 55-61, 2019.*

Passive acoustic monitoring of underwater sounds is an emerging discipline that can be used to guarantee that anthropogenic noise meets acceptable limits, to detect the presence of cetacean species, and to ensure sustainable exploitation of our oceans and seas. In this scenario, graphical representation techniques play a key role in helping to reveal seasonal structures of human made noises. Nevertheless, for very long temporal series, it might be challenging to find a graphic visualization technique that allows representing a time range that is long enough to capture these seasonal events, while at the same time preserving short isolated events. We propose a framework for the creation of such visualization techniques and analyze the different stages involved: data reduction, color encoding, and signal processing on graphs. All of this is applied to data from deployments in two marine protected areas in order to provide an acoustic panorama and identify seasonal events.

DOI: *10.1016/j.apacoust.2018.12.009*

· ***Comparative Study of Coupling Techniques in Lamb Wave Testing of Metallic and Cementitious Plates,*** *S. Vázquez, J. Gosálbez, I. Bosch, A. Carrión, C. Gallardo and J. Payá, Sensors, 19, 4068, 2019.*

Lamb waves have emerged as a valuable tool to examine long plate-like structures in a faster way compared to conventional bulk wave techniques, which make them attractive in non-destructive testing. However, they present a multimodal and dispersive nature, which

hinders signal identification. Oblique incidence is one of the most known methods to generate and receive Lamb waves and it is applied in different experimental arrangements with different types of sensors. In this work, several setups were conducted and compared to determine the optimal ones to launch and detect ultrasonic Lamb waves, especially in non-homogeneous specimens. The chosen arrangements were contact with angle beam transducers, immersion in a water tank, localised water coupling using conical containers and air coupling. Plates of two different materials were used, stainless steel and Portland cement mortar. Theoretical and experimental dispersion curves were compared to verify the existence of Lamb modes and good correspondence was achieved.

DOI: *10.3390/s19194068*

· ***Workshop Soundcool: Smartphones, Tablets and Kinect for Colaborative Creation,***

Jorge Sastre, Roger Dannenberg at the International Computer Music Conference, ICMC2018, Daegu (Korea), 5-10 Aug., 2018.

In this Workshop Soundcool was introduced to the international computer music research community and a jam session with Soundcool was produced by the participants, see https://bit.ly/2kameUd. The conference was co-organized by Prof. Tae Hong Park from the New York University (NYU), and with his approval the program NoiseGate-Soundcool "Seeing Music | Hearing Images" for kids https://nycemf.org/noisegate-soundcool/ was introduced at the ICMC2019 held at NYU https://bit.ly/2k8d2zy, New York, June 6-23, 2019.

2.2.- AWARDS.

In early 2019, our Soundcool engineers created the new 3.1 application that integrates control surfaces for both audio and video modules into a single platform and the functionalities of some modules have been improved. This has expanded Soundcool to be able to carry out more complex audiovisual projects. Moreover, an Augmented Reality app that allows to visualize the Soundcool virtual controls in smartphones and project them has been developed. This app has been used at the World Science Festival, where Soundcool had a workshop, a stand https://youtu.be/79Q_uGijp3k, and several performances, see https://youtu.be/l34X-qxln0Y

The multimedia opera La Mare dels Peixos (The Mother of Fishes) was performed on May 9 and 10 at the Palau de les Arts from Valencia (Spain) with a new Soundcool production. New performances are programmed in Mexico City with the Monterrey Institute of Technology and Higher Education in 2019, and in Pittsburgh (USA) in 2020. Other professional works have been presented such as Floating in the Deep Blue for percussion and Soundcool live electronics https://youtu.be/KPSiPHTfvzo, Chapitres for Symphonic Band, Soundcool live electronics and narrator https://youtu.be/f_Wt3fKi82E, Hope https://youtu.be/SFseQG5Mr-0, etc. Soundcool has been presented at the Spanish education community at the Con Euterpe Conference 2019. In this conference several workshops were given to teachers https://youtu.be/MggbjKwddGU and a Telegram help group was created to share experiences. The Soundcool team is giving support to that group. Install the Telegram app at your smartphone or tablet and click on https://t.me/soundcool for joining the Soundcool help group. It is organized with hashtags and many questions have been already answered. We have new web design http://soundcool.org in English and Spanish languages with an interesting FAQs link http://soundcool.org/en/faqs-doubts/. Moreover, the KA1 Erasmus+ project Collaborative creation and creativity through Music has adopted Soundcool. (2017-1-ES01-KA101-036693)